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VII. *Researches on the Tides.—Seventh Series. On the Diurnal Inequality of the Height of the Tide, especially at Plymouth and at Singapore; and on the Mean Level of the Sea. By the Rev.* W. WHEWELL, *M.A. F.R.S., Fellow of Trinity College, Cambridge.*

Received March 7,—Read March 9, 1837.

THE Inequality of the Tides which is the subject of the present paper, though theoretically very curious, and practically very important, has hitherto been hardly noticed, and its laws have never been generally stated. By means of the materials which I have had in my hands, I have not only been able to obtain a rule agreeing with the observations to an extraordinary degree of precision, but I have found and analysed a case in which this inequality assumes a very remarkable form, so as materially to disguise the general circumstances of the tides, and to explain other cases in which the usual features are entirely obliterated.

The inequality of which I speak is the Diurnal Inequality, by which the tide of the morning and evening of the same day differ. The difference is often very considerable, especially in the height of the water; and naval officers have often found the preservation or destruction of a ship to be caused by this difference, without being aware that it was subject to steady rules, and was capable of being predicted. The small number of places for which I have been able to procure the proper observations will not permit me at present to state the circumstances of the inequality as they occur all over the surface of the ocean; but I am, by fortunate circumstances, able to trace its laws in some very remarkable instances, situated in very widely separate regions of the globe.

Sect. I. *Diurnal Inequality at Plymouth.*

I will first treat of the diurnal inequality as it appears at Plymouth, at which port good tide observations are regularly made under the direction of Mr. ALEXANDER LUMSDALE and Mr. WILLIAM WALKER, the Master Attendant and Assistant Master Attendant of the Dock-yard.

It has long been known that both at Plymouth and at other places there is commonly a difference in the morning and evening tide of the same day. It is stated by COLEPRESS in 1668*, that at that port "the diurnal tides from about the latter end of March till the latter end of September are about a foot higher in the evening than in the morning; that is, every tide which happens after twelve in the day before twelve at

* Philosophical Transactions, vol. iii. p. 633.

night, and *vice versâ* the rest of the year." But we shall soon see that this way of expressing the fact, by speaking of morning and evening tides, is quite inaccurate.

It is easily seen that the theory of the tides, which supposes them to be produced by the ocean assuming its form of equilibrium under the influence of the moon's attraction, would give a diurnal difference of the tides: for if the moon have 20° north declination, the tide spheroid will have one pole in latitude 20° north, and the other in 20° south latitude; and as the earth revolves, a place in 50° north latitude will have the tide which belongs to these two poles alternately: and as it is 30° from one pole and 70° from the other, the two tides will be very unequal.

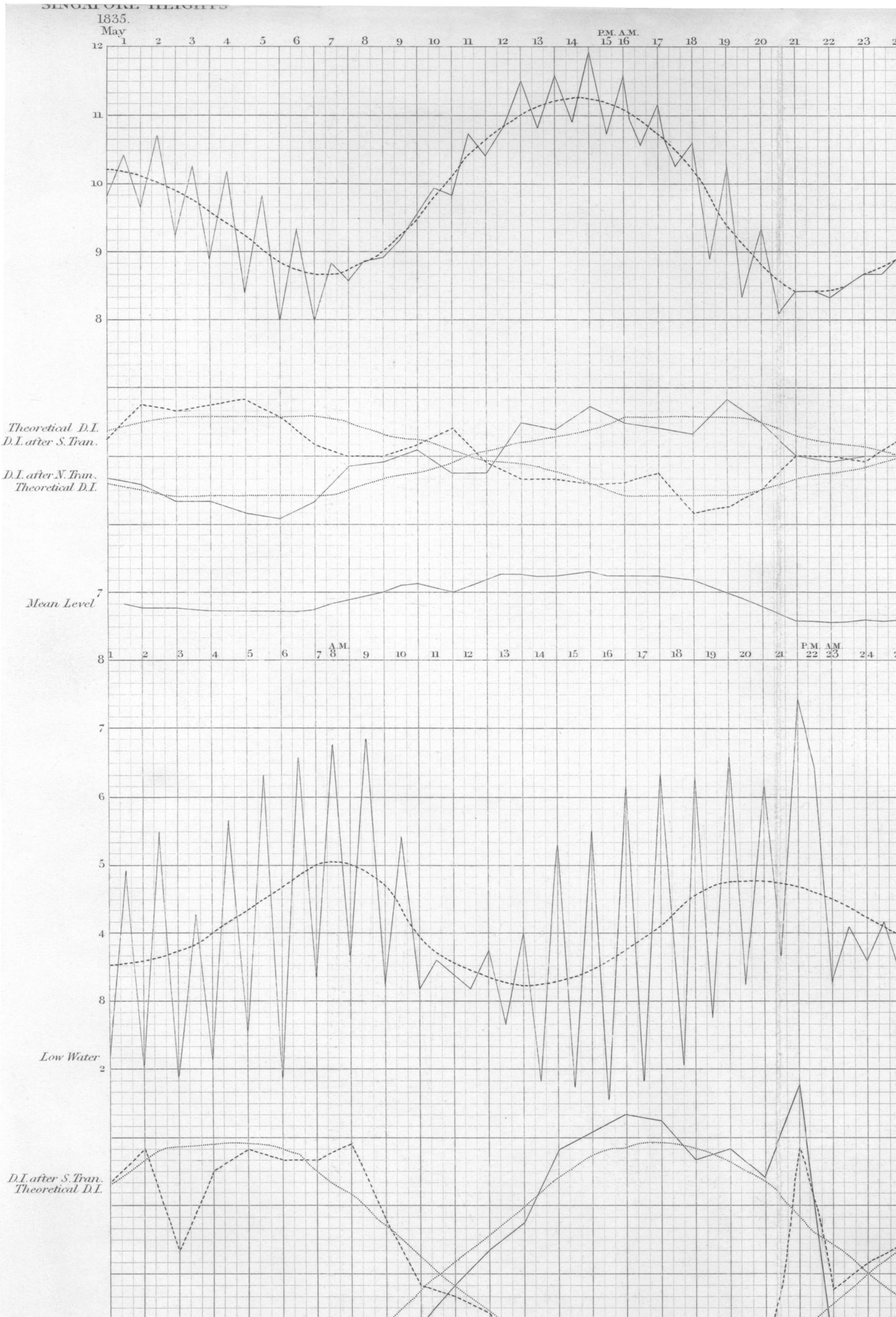
Now it has been found, with regard to all the other inequalities of the tides, that they follow the *laws* of the tides of the equilibrium-theory, although the *constant elements* (the *magnitudes* and *epochs*) can be determined only by observation. Finding that the diurnal inequality was very clearly marked in the Plymouth observations, I did not hesitate to attempt to trace its laws, by assuming this kind of correspondence with the equilibrium-theory. The result confirmed the assumption in the most striking manner, as I shall show.

According to the equilibrium-theory, the tide which belongs to a *south* transit of the moon should be the *greater* (of the two on the same day) when the moon's declination is *north*; when the moon crosses the equator, the difference of the two tides vanishes; when she has *south* declination, the tide which belongs to her *south* transit is the *smaller*. The contrary (as to greater and smaller) will be true of the tide which belongs to the *north* or *inferior* transit.

We cannot know, except by observation, to what transit of the moon any tide *belongs*; but it is manifest that if we begin with any tide, the tides must belong alternately to south and north transits, and therefore the above alternation of greater and smaller tides, as the moon has north or south declination, must come into view.

Accordingly I set off the observed heights of high water at Plymouth as ordinates of a curve, as seen in Plates II. and III. The zigzag form of the lines, appearing, vanishing, and reappearing, about once a fortnight, with great steadiness, showed that the diurnal inequality really existed in the observations. A line was drawn *by the eye*, cutting off from these zigzags equal portions above and below, and this was taken as the mean high water cleared of the diurnal inequality. The *excesses* or *defects* of the observed height and this mean height were then set off from another axis; those which belonged to the high water next following a south transit forming one curve, and the alternate tides, which follow a north transit, forming another curve. These curves were both of them found to have their ordinates alternately positive and negative at intervals, corresponding to the change of the moon's declination from north to south, and the contrary.

But though the order and cycles of these changes were the same for the observed diurnal inequality and for the lunar declination, the epochs of the changes were not the same. According to theory, as we have said, the diurnal inequality ought to



SINGAPORE HEIGHTS
1835.
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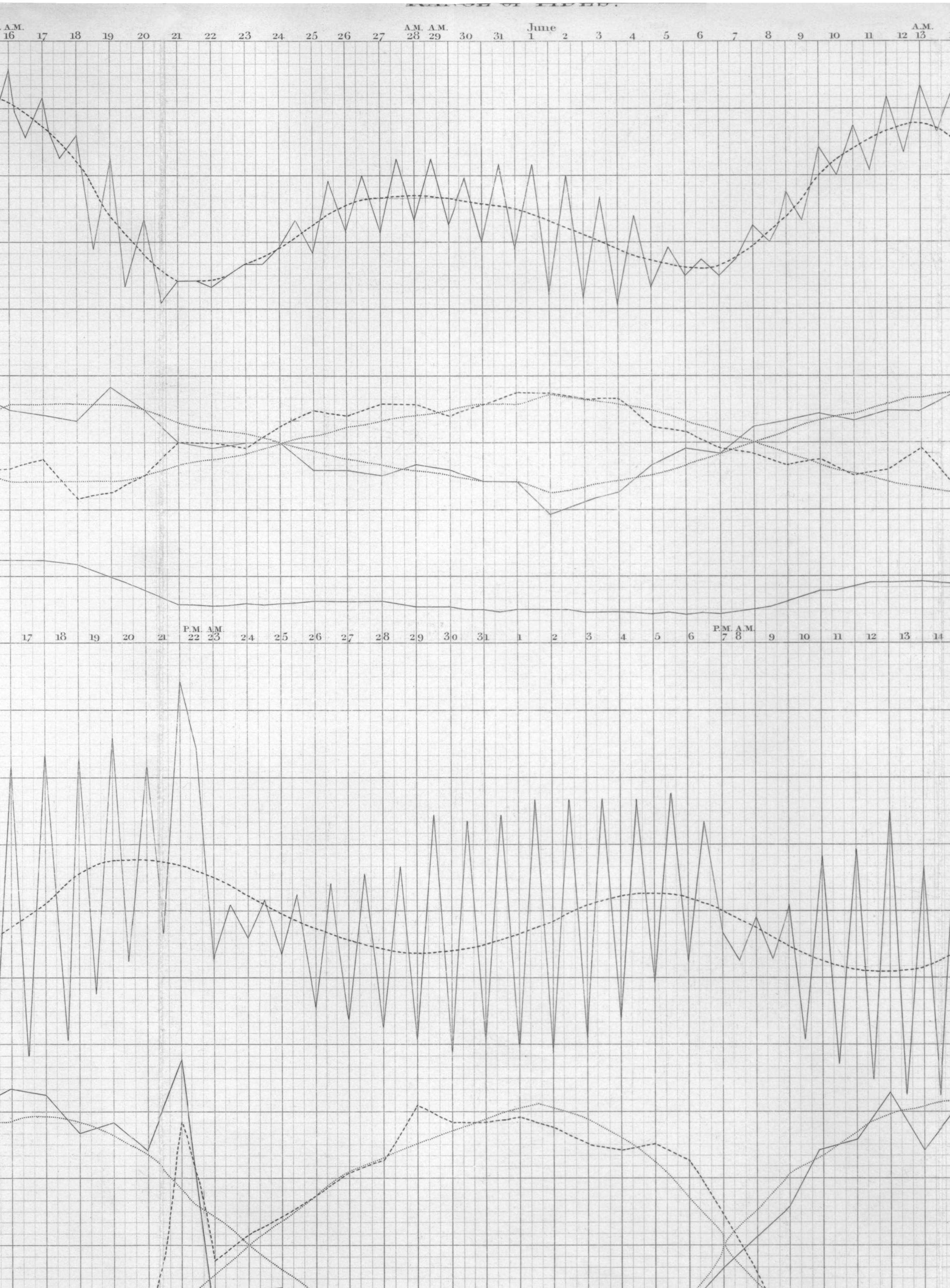
P.M. A.M.
Theoretical D.I.
D.I. after S. Tran.
D.I. after N. Tran.
Theoretical D.I.
Mean Level
A.M.
P.M. A.M.
Low Water
D.I. after S. Tran.
Theoretical D.I.


A.M.
16 17 18 19 20 21 22 23 24 25 26 27
A.M. A.M.
28 29 30 31
June
1 2 3 4 5 6 7 8 9 10 11 12
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17 18 19 20 21
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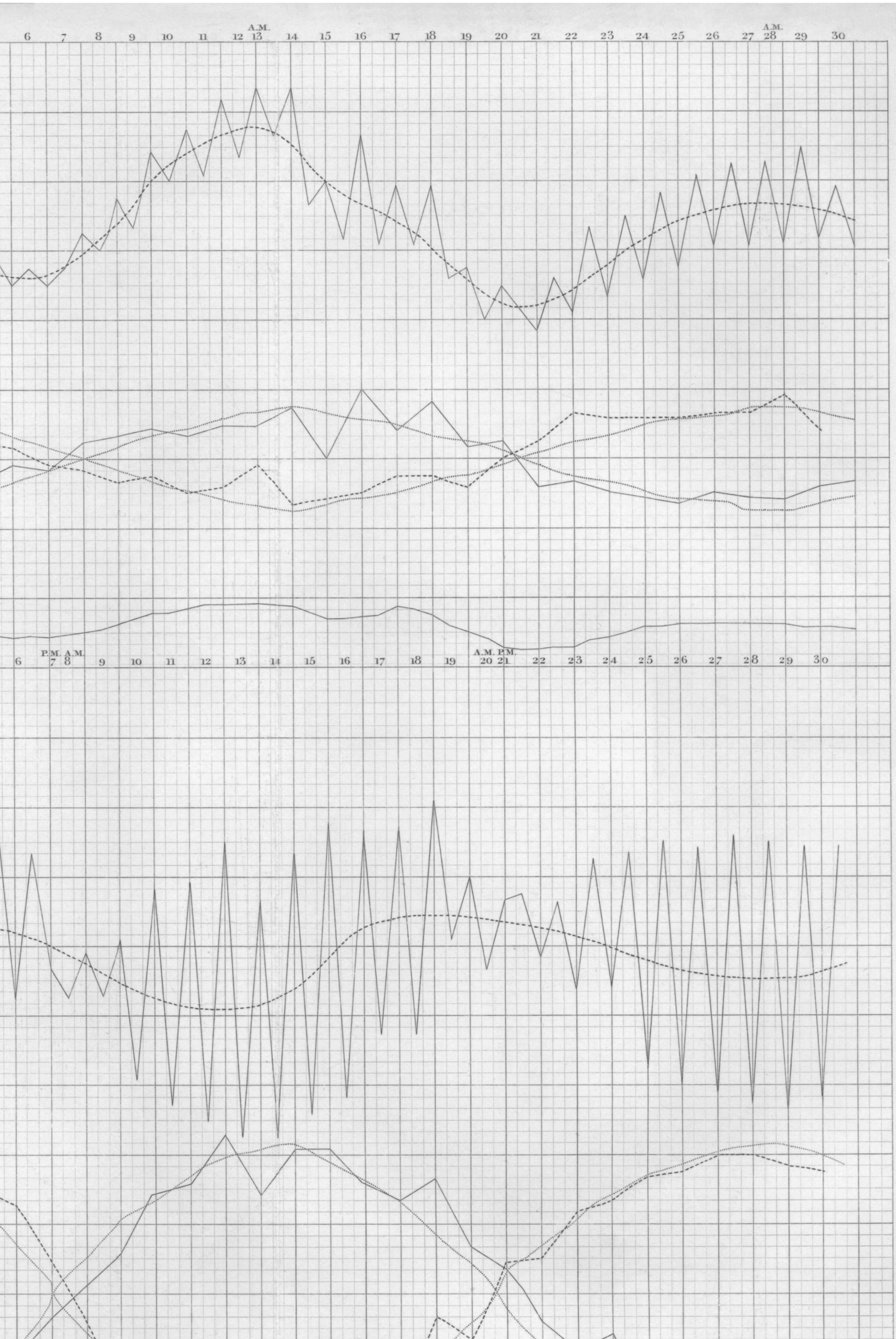
22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6
P.M. A.M.
7 8 9 10 11 12 13 14



6 7 8 9 10 11 12 A.M. 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 A.M. 28 29 30
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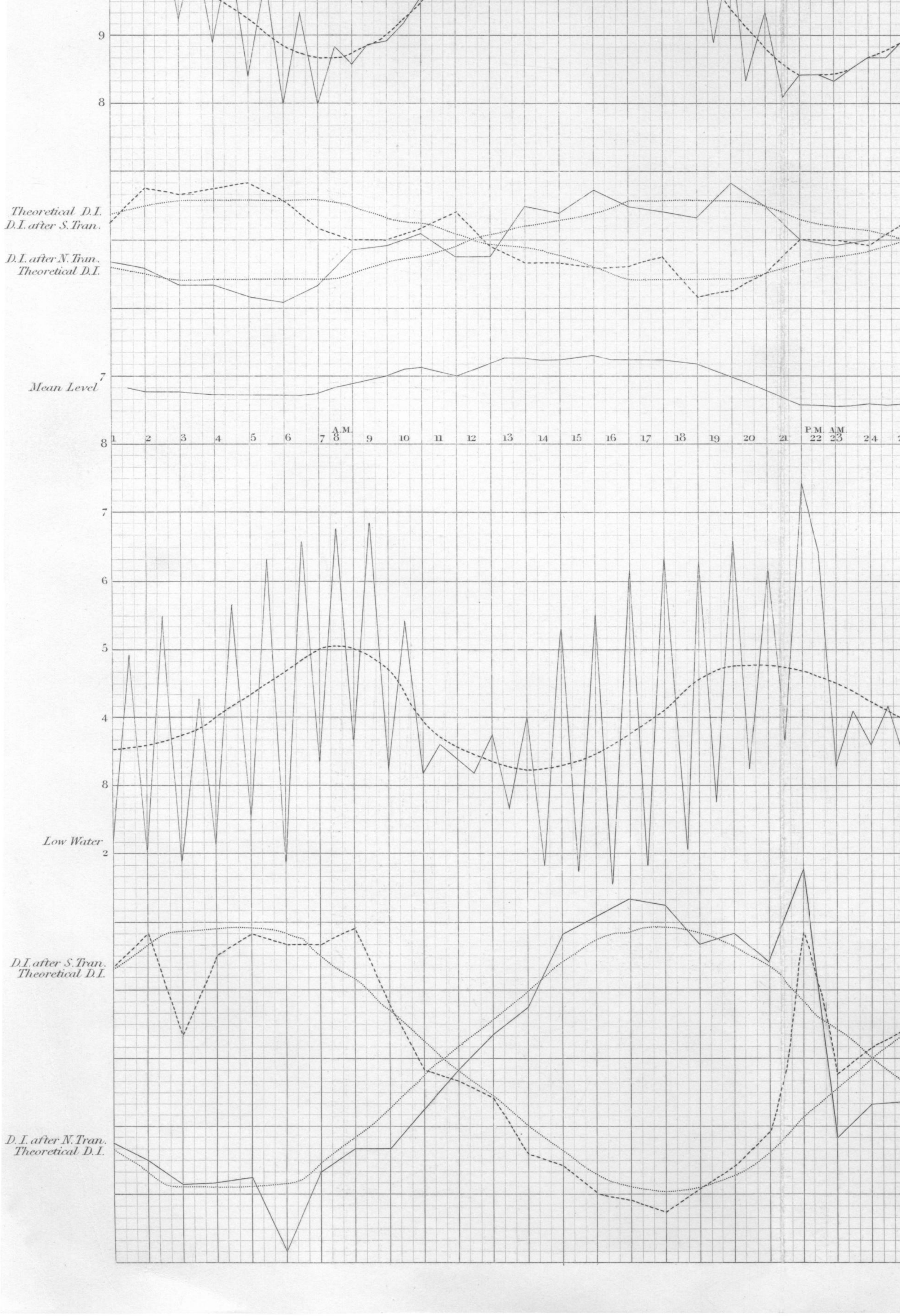

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Theoretical D.I.
D.I. after S. Tran.
D.I. after N. Tran.
Theoretical D.I.
Mean Level
7
A.M.
P.M.
A.M.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
8
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6
5
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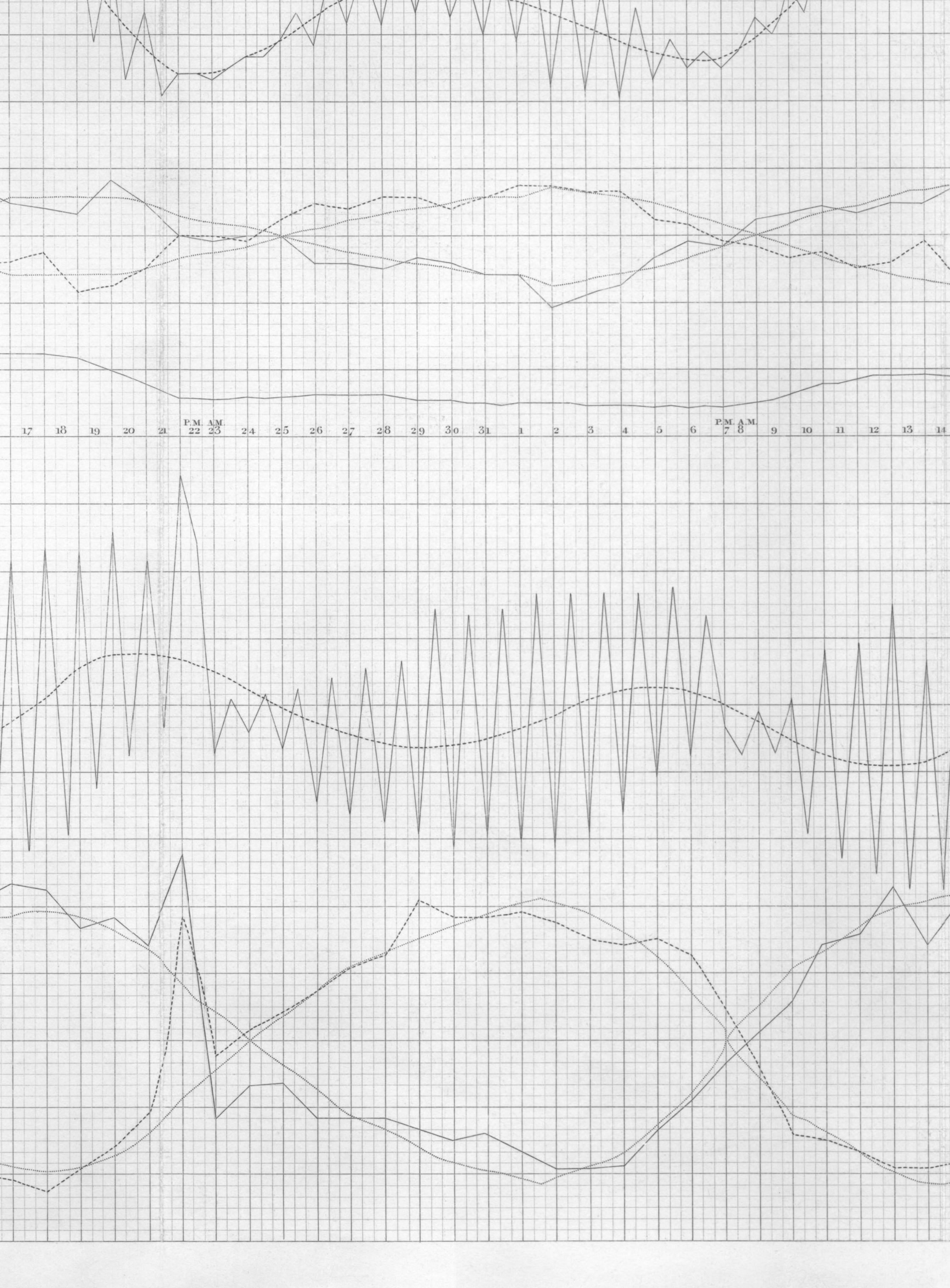
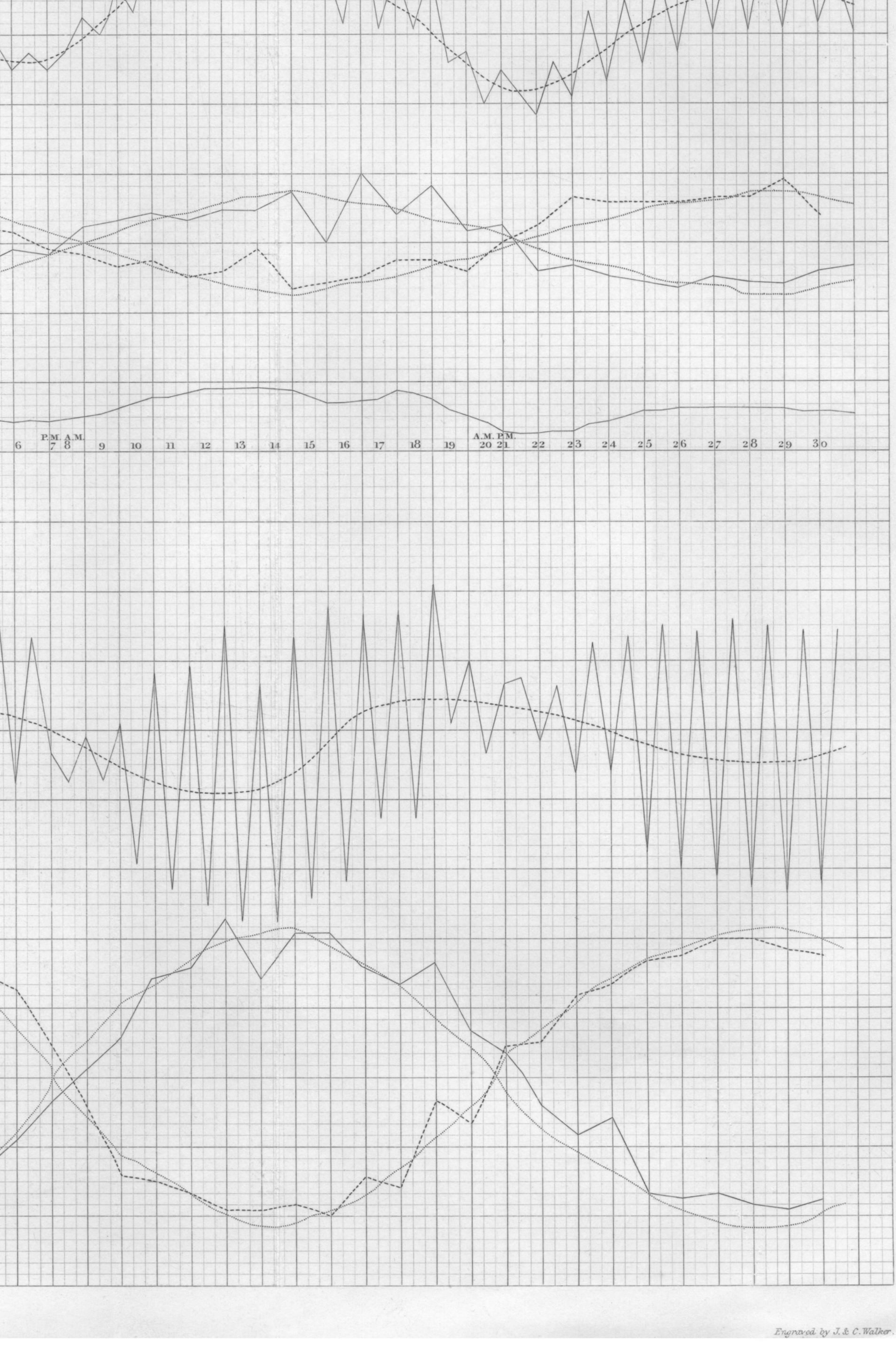
3
Low Water
2
D.I. after S. Tran.
Theoretical D.I.
D.I. after N. Tran.
Theoretical D.I.


P.M. A.M.
P.M. A.M.
17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14



Engraved by J. & C. Walker.

vanish when the moon is in the equator. But it appeared that in fact the diurnal inequality did not vanish till about four days after that period.

By taking the moon's declination four days anterior to the day of observation, and reducing it to a proper scale, it was found that the amount of the diurnal inequality could be represented with great accuracy, as may be seen in the Plates, which are specimens of a comparison of this kind made for the whole of the years 1833 and 1834.

It is to be observed, however, that the calculation of the diurnal inequality from the declination was made by means of a coefficient which was somewhat different in different months. Thus the usual multiplier of the declination for the diurnal inequality of high water at Plymouth is $\frac{1}{4}$; that is, 4° of lunar declination produce a difference of height of 1 inch: but in some cases the coefficient is $\frac{1}{3}$ or more; in others it is $\frac{1}{6}$. These differences appear to arise in part from the height of the tide itself; for the inequality is theoretically proportional to the whole lunar tide; partly to the effect of the sun, according to different seasons of the year. Yet there appears to be still some other unexplained cause of the variation of this multiplier; for there are differences in its value which cannot be referred to the causes just mentioned, and which operate, during a lunation or a semilunation, too uniformly to be accidental. We may take the coefficient at Plymouth to be $\frac{1}{4}$, which is the value on which the curves represented in Plate II. are constructed. I am persuaded that no one accustomed to the comparison of theoretical formulæ with observation can look at those curves without being persuaded that the formula exhibits the true law of nature.

As has been said, the declination of an anterior period has been taken. The period employed was the *fifth* lunar transit preceding the tide. Thus the diurnal inequality of January 6, 1834, is determined by the declination on January 2, at $5^h\ 44^m$ A.M., the time of the moon's transit. The assumption of this period is confirmed by the general agreement of the results.

From what has been said, the inaccuracy of the statements of this inequality, as an excess of the evening tide at particular seasons, and of the morning tide at other seasons, will readily appear; for the high water at Plymouth is, on the average, five hours after the moon's transit. Suppose the moon to move in the ecliptic, which is her average path: when the sun's right ascension is five hours, (that is, about June 7,) the tide which follows the moon's transit will follow the sun's transit also, as soon as the moon is north of the equator; that is, if the diurnal inequality were regulated by the moon's place on the same day, the afternoon tide would be greatest; and so it would continue till the moon was seven hours after the sun, at which period the tide would be twelve hours after the sun, and the tide following the moon would become the morning tide. But at the same time the moon would pass to the south of the equator; and therefore the tide following the moon would be the smaller. Therefore in this situation the evening tide would be the greater during the whole lunation.

But suppose the sun's right ascension to be eight hours, (July 21,) then, when the

moon begins to have north declination, the tide which follows her, and which is therefore the greatest, is three hours before the sun, and is a morning tide. When the moon's right ascension becomes three hours, (that is, after about one eighth of a lunation,) the tide following the moon, which is still the greater, (because the declination is still north,) becomes the evening tide. The evening tide continues the greater till the moon's right ascension becomes twelve hours, when she passes to the south of the equator, and the tide following the moon, which is nine hours after the sun, and still the evening tide, becomes the smaller; and this continues till the moon is seven hours from the sun, or in fifteen hours right ascension, at which period the tide which follows her becomes the morning tide, and the evening tide is again the greater. Thus in this position the morning tide is greater during six hours of the moon's motion in right ascension (from the sun), and the evening tide is greater during the remaining eighteen hours; that is, the evening tide is the greater during three fourths of the lunation.

We might in the same manner trace the changes which take place in other positions of the sun; but this is unnecessary. The effect of the inequality may be calculated by the tables which are added at the end of this paper.

The height of low water at Plymouth is also affected by a diurnal inequality. It follows the same law as the inequality of high water; its epoch is the same; and its multiplier for May, June, July, August, 1834, is $\frac{1}{5}$, $\frac{1}{6}$, $\frac{1}{7}$, $\frac{1}{9}$, respectively.

Sect. II. *Diurnal Inequality at Singapore.*

By the Hydrographical Office of the Admiralty I was furnished with about a year's observations of the tides of Singapore, from August 1834 to August 1835, made by Mr. W. Scott, the Master Attendant at that port, in pursuance of directions given by the Directors of the East India Company.

These observations, from the very curious nature of the results to which they lead, I consider as more remarkable and valuable than any series of equal extent which has fallen under my notice.

On laying down the heights of high water, it appeared that the early part of the series was very irregular, obviously from the imperfection of the observations; but beginning with January 1835, the curve was tolerably regular; and during the greater part of the subsequent time, the inequalities (which the observers could not know) were so clearly marked, and so steady in their course, that it was impossible to doubt the goodness of the observations.

I proceeded to examine these in the manner already described for the Plymouth observations, and found a diurnal inequality nearly agreeing in law and in amount with that at Plymouth; the only difference being, that instead of four days it was here found necessary to take the lunar declination *a day and a half* preceding the tide, or, more exactly, at the *interpolated* or north lunar transit which intervened between the second and third south transit preceding the tide.

The amount of the inequality is nearly the same as at Plymouth, or rather greater, being, in the most regular parts of the series, one inch of height for every three degrees of declination.

In these parts of the series (May, June, July, 1835,) the coincidence of the formula with observation is as close as at Plymouth. In other months (March, April, and August,) there are discrepancies; but we cannot consider these as throwing any doubt on the general correctness of the formulæ, when we see how well it represents the observed diurnal inequality of low water, which is much more marked than that of high water.

The diurnal inequality of low water at Singapore is of a magnitude which it would have been impossible to anticipate. It makes a difference in many cases of not less than six feet between the height of the morning and evening tide; the whole rise of the mean tide being only seven feet at spring tides, and the difference of mean spring and neap tides not more than two feet.

This enormous diurnal inequality conforms, with deviations which are slight considering its magnitude, to the same formula which we have already stated, the epoch being the same as that for high water; that is, thirty-six lunar hours anterior to the last transit. The multiplier is different in different months, varying from $\frac{3}{4}$ to 1; so that each degree of the moon's declination produces an effect of nearly an inch in the height of low water, or two inches in the difference of two successive low waters.

Sect. III. *On the Diurnal Inequality at some other places, and on the General Laws of its Progress.*

I have not found any register of tide observations which exhibits the diurnal inequality so clearly and regularly as Plymouth and Singapore, although I have tried many series observed in different parts of the world. It may however be detected in many, perhaps in most, places. The comparison of the circumstances of this inequality in different places is curious and interesting, and especially the change which the *epoch* undergoes; that is, the anterior period at which the moon's declination corresponds to the amount and direction of the inequality.

Bristol.—Mr. Bunt, who has bestowed very great labour upon the analysis of tide observations made at Bristol, has, among other inquiries, endeavoured to determine the diurnal inequality at that port. The results are not very regular, but they lead him to the conclusion that the inequality vanishes at nearly the distance of five days' motion of the moon from her nodes; that is, the epoch is *five days*. The amount of the inequality is five or six inches each way, at the greatest.

Liverpool.—The diurnal inequality of the heights at Liverpool has been detected by Mr. Bywater from the observations, and introduced by him into his tide tables. I have already remarked in these Researches *, that the epoch of the diurnal inequality at this port is about *six days and a quarter*; but I do not conceive the determina-

* Fifth Series. Philosophical Transactions, 1836, p. 133.

tion to be very exact, since the inequality has been tabulated by means of the calendar months, and thus has been referred to the moon's mean motion in the ecliptic instead of being referred to her actual motion in her own orbit. The greatest effect is about *half a foot* in excess and in defect.

Leith.—Tide observations have been made at Leith Harbour for several years. I have examined these for the diurnal inequality, but it does not appear with any great steadiness and regularity. Still its existence is very obvious; and as the determination of its epoch is a curious point, I attempted it in the following manner:

Leith Tides, 1835.

Periods of Max. Diurn. Ineq.	Tides after S. Transit.	Middle of Max.	Inequality vanishes.	Moon's dec. vanishes.	Difference. Days.
Feb. 15 to 25.	less	Feb. 20.	Feb. 27.	N. Feb. 15.	12
March 1 to 13.	greater	March 7.	March 13.	S. March 1.	12
March 15 to 25.	less	March 20.	March 27.	N. March 15.	12
March 28 to April 8.	greater	April 3.	April 11.	S. March 29.	13
April 15 to 22.	less	April 19.	April 26.	N. April 11.	13
April 29 to May 9.	greater (*small*)	May 4.	May 9.	S. April 24.	15
May 11 to 18.	less	May 15.	May 22.	N. May 9.	13
May 22 to June 7.	greater (*small*)	May 30.	June 6.	S. May 21.	[16]
June 9 to 14.	less	June 12.	June 17.	N. June 5.	12
June 15 to 30.	irregular	June 23.	June 29.	S. June 18.	[11]
July 1 to 8.	less (*small*)	July 5.	July 10.	N. July 2.	[8]
July 12 to 19.	greater (*irreg.*)	July 16.	July 20.	S. July 15.	[5]
July 21 to 27.	less (*small*)	July 24.	August 3.	N. July 30.	[5]
August 10 to 17.	greater	August 14.	August 22.	S. August 11.	11
Aug. 26 to Sept. 4.	less	August 31.	Sept. 6.	N. August 26.	10
September 8 to 18.	greater	Sept. 13.	Sept. 19.	S. Sept. 8.	11
September 20 to 30.	irregular	Sept. 25.	Sept. 30.	N. Sept. 22.	[8]
October 1 to 11.	greater	October 6.		S. October 5.	

Among all the irregularities of the Leith tides, it is easily seen from the curves, when they are laid down, that there is a diurnal inequality, in consequence of which the *tide following the south transit* of the moon becomes alternately the greater and the smaller, as the moon's declination changes from south to north, and the reverse. The times when this inequality is large can be picked out more decidedly than the times when it vanishes, and I therefore determined the epoch by means of the greatest inequality, supposing the times when it vanishes to be midway between two successive maxima, as may be seen in the preceding Table.

Rejecting those cases in which the inequality is very small or altogether irregular, it appears that the inequality vanishes *twelve days* after the moon's inclination vanishes. This is certainly a very extraordinary result; for it is difficult to conceive how the effect of the moon's action can require so much time to manifest itself. Yet there can hardly be any doubt of the fact; for it is verified in 11 semilunations out of 17, and is inconsistent with none; the variations in the interval being not greater than might be expected, supposing the law to be true. It may be observed, that by these variations the inequality is in some cases thrown back more than a whole semilunation. Thus the inequality which prevails before April 26, and vanishes about that day, is not produced by the series of declinations which vanish on April 24, but by the series which vanish on April 11. To suppose the reverse would be impossible; for that would make it necessary to suppose that the inequality vanishes on Feb. 27, in consequence of the declination vanishing two days *later*, or March 1; that is, that the effect precedes the cause.

In the system of tide observations made on the coasts of Europe and America in June 1835, of the results of which an account was given in the Sixth Series of these Researches*, it appeared that the diurnal inequality on the east coast of Scotland was, during that semilunation, irregular, passing over a tide in the middle of the series. This and other anomalies in the diurnal inequality, as it appears on the coasts of the German Ocean, appear to show that the waters in that region are affected by the mixture of more than one tide. In the most material point, however, the observations of June 1835 confirm the results of our present inquiry; namely, in showing that the diurnal inequality travels more slowly than the other inequalities. On the east coast of America, the changes of this inequality appear to be contemporaneous with the corresponding changes of the moon's declination, and the epoch is *zero*. On the coasts of Spain, Portugal, and France, it is successively *two* and *three days*. And this is quite consistent with the fact that this epoch is *four* days on the coast of Cornwall and Devonshire, *five* days at Bristol, *six* at Liverpool, and *twelve* at Leith. That the diurnal inequality should thus creep from place to place on successive days is difficult to explain; but the laws of fluid motion are so little known, that we cannot collect from hydraulical views any good reason for doubting this curious fact. The fact is certainly not easily reconciled with our conception of the

* Philosophical Transactions, 1836, Part II. p. 304.

tides of remote places, as produced successively by the motion of the same "tide-wave;" but it is already established beyond doubt, by the observations made on the two sides of the Atlantic in 1835, that tides which were supposed to be brought by the same tide-wave differ materially in their circumstances. As I have already stated*, "On the 9th, 10th, and 11th of June 1835, when the diurnal inequality was great in America it was nothing in the West of Europe; and on the 18th and 19th, when this inequality had vanished in America, it was great in Europe." Are we to doubt whether the tide-wave which brings high water to America and to Europe at the same moment be the same wave? A sound hydrodynamical view of all the circumstances must enable us to decide; but for this purpose more observations are needed, especially observations on the coast of America, where the diurnal inequality is great, and where, on several accounts, a knowledge of its laws would be interesting to us.

Another remarkable circumstance in the progress of the diurnal inequality is, that it appears much more distinctly and steadily at some places than at others which are near them: nor does it seem easy to assign any rule which it follows in this respect. It is very marked and almost universal on the coast of the United States, and was conspicuous in the observations of June 1835 on the coasts of Spain and Portugal, the west coast of France, and parts of the west coast of Ireland. Yet at places interjacent among those at which it was thus displayed it could not be detected; nor did the circumstances easily allow of my ascribing this to any defect of exactness in the observations. In like manner it is large on the east coast of New Holland, as we know from COOK's account of his getting his ship off a reef by means of it; and the north and south coasts of Australia appear to exhibit the extreme case of it, as we shall see. We might therefore suppose that it affects the whole of the Indian Ocean: yet at Keeling Island, in the centre of that ocean, it does not decidedly show itself. Such, at least, is the result of observations made by Captain FITZ ROY, from April 2 to April 8, 1836, with which I have been furnished by his kindness.

Sect. IV. *On extreme Cases of great Diurnal Inequality.*

If we consider the motion of the surface of the water in cases where, as at Singapore, the diurnal inequality is very great, we shall see that this motion is very different from the alternate equal ascent and descent which would occur if there were no such inequality. In order to exhibit this peculiarity, I have represented this motion in Plate IV. for Plymouth and for Singapore, as observed in the months of May and June. It will be seen that at Plymouth the curve of the motion of the surface oscillating upwards and downwards by nearly equal distances; the main feature of inequality is the difference of spring and neap tides, although the diurnal inequality is very clearly visible. But at Singapore the alternate oscillations make no approach to equality; at some parts of the series the alternate tides seem to be on the point

* Philosophical Transactions, 1836, Part II. p. 302.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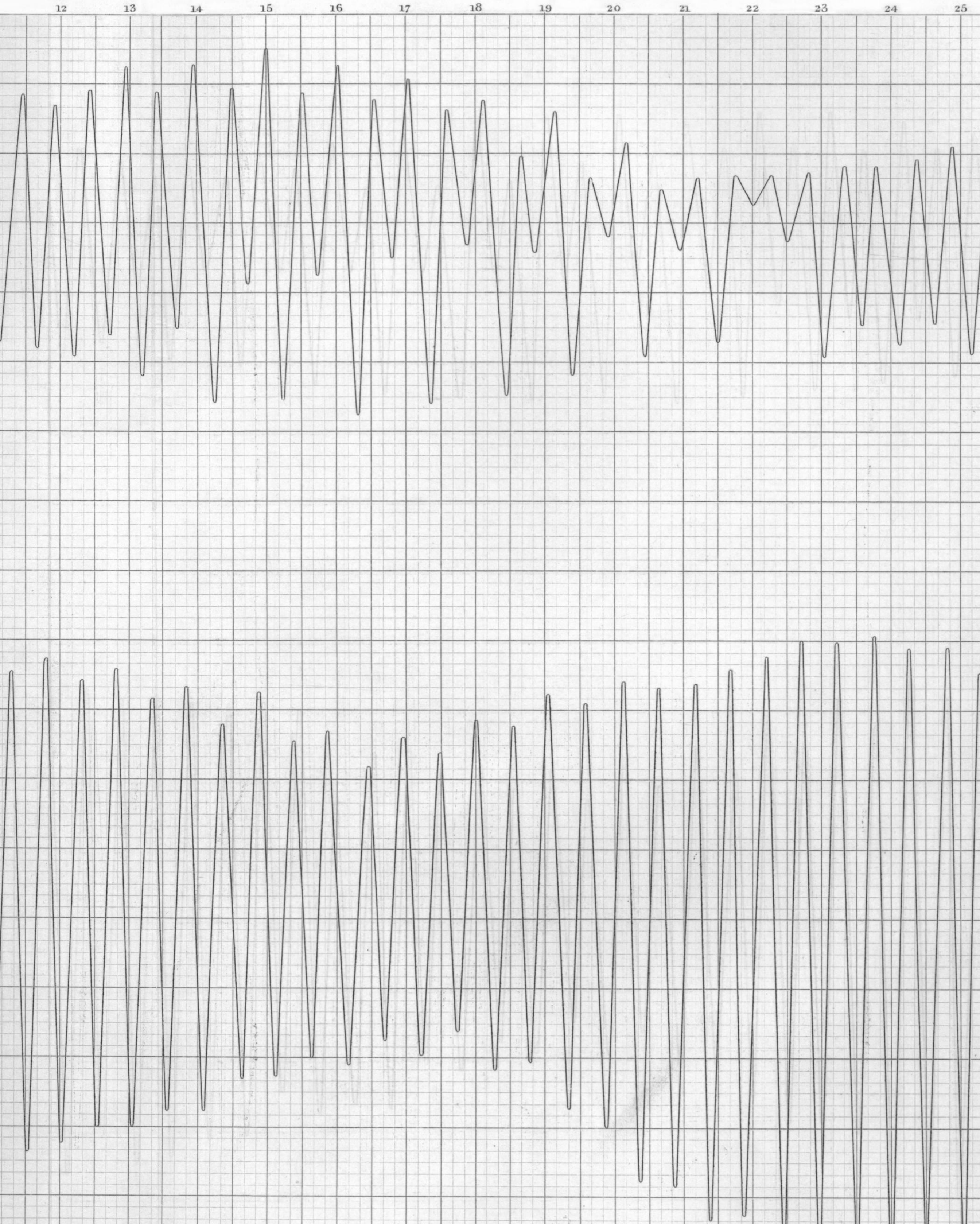
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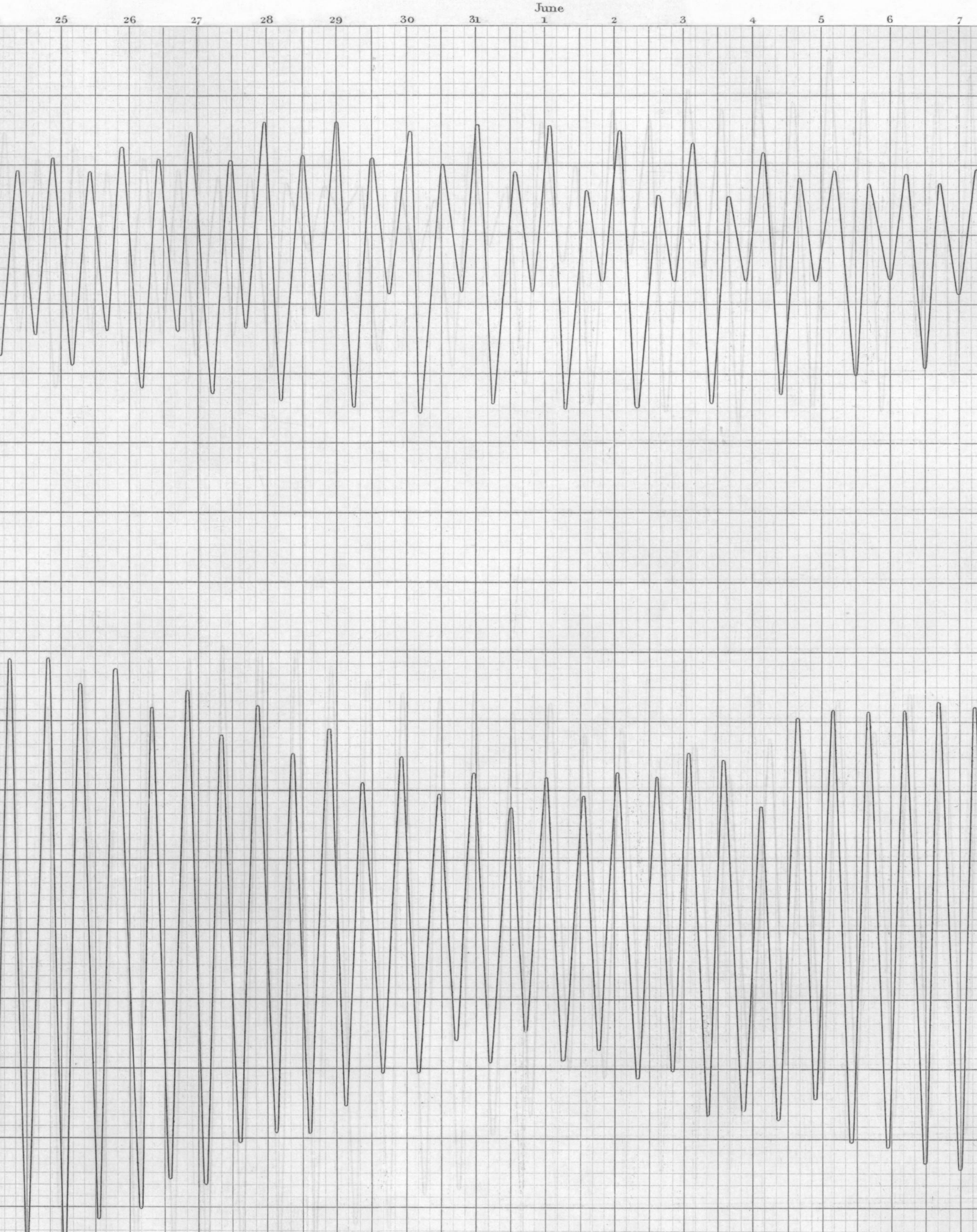

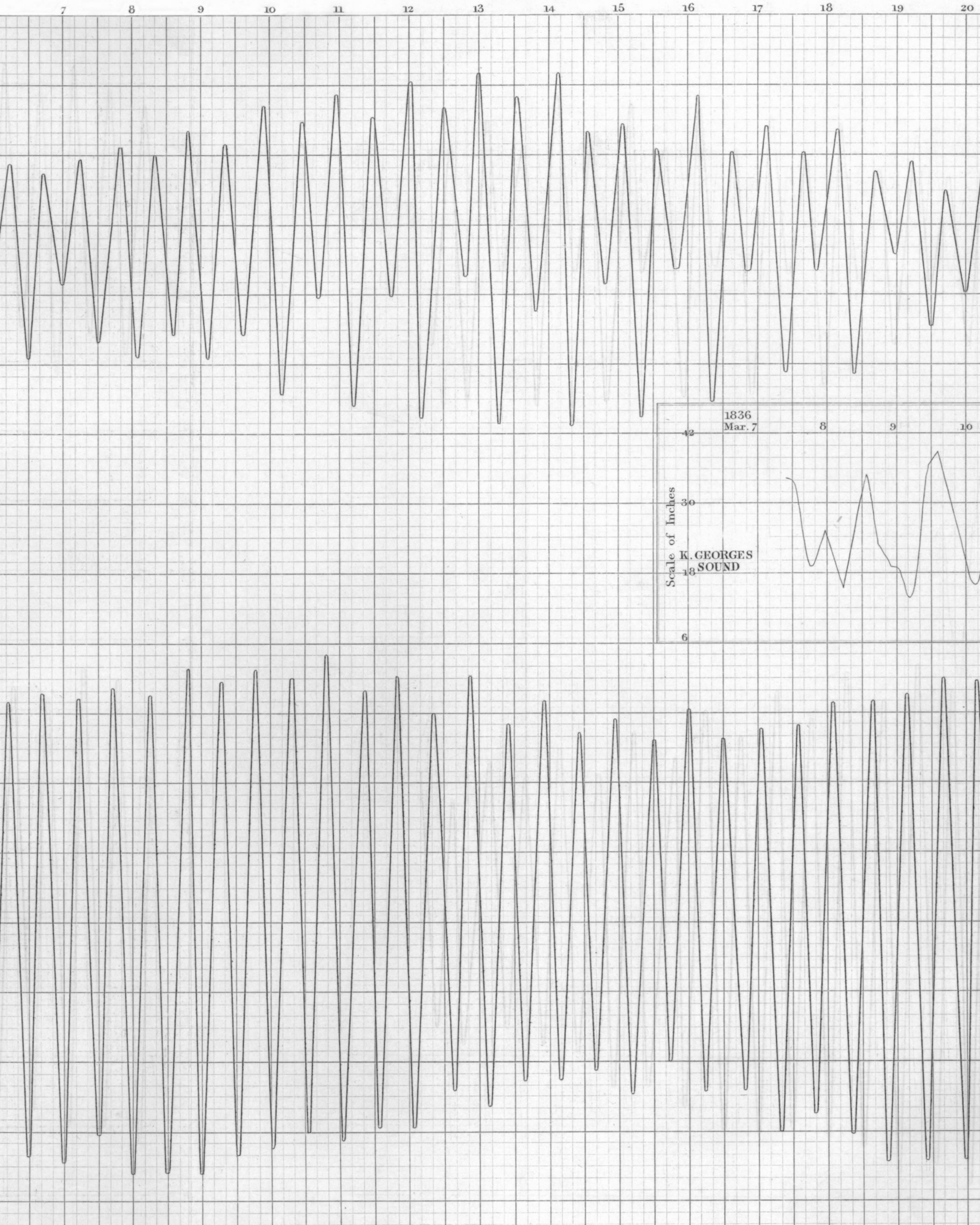
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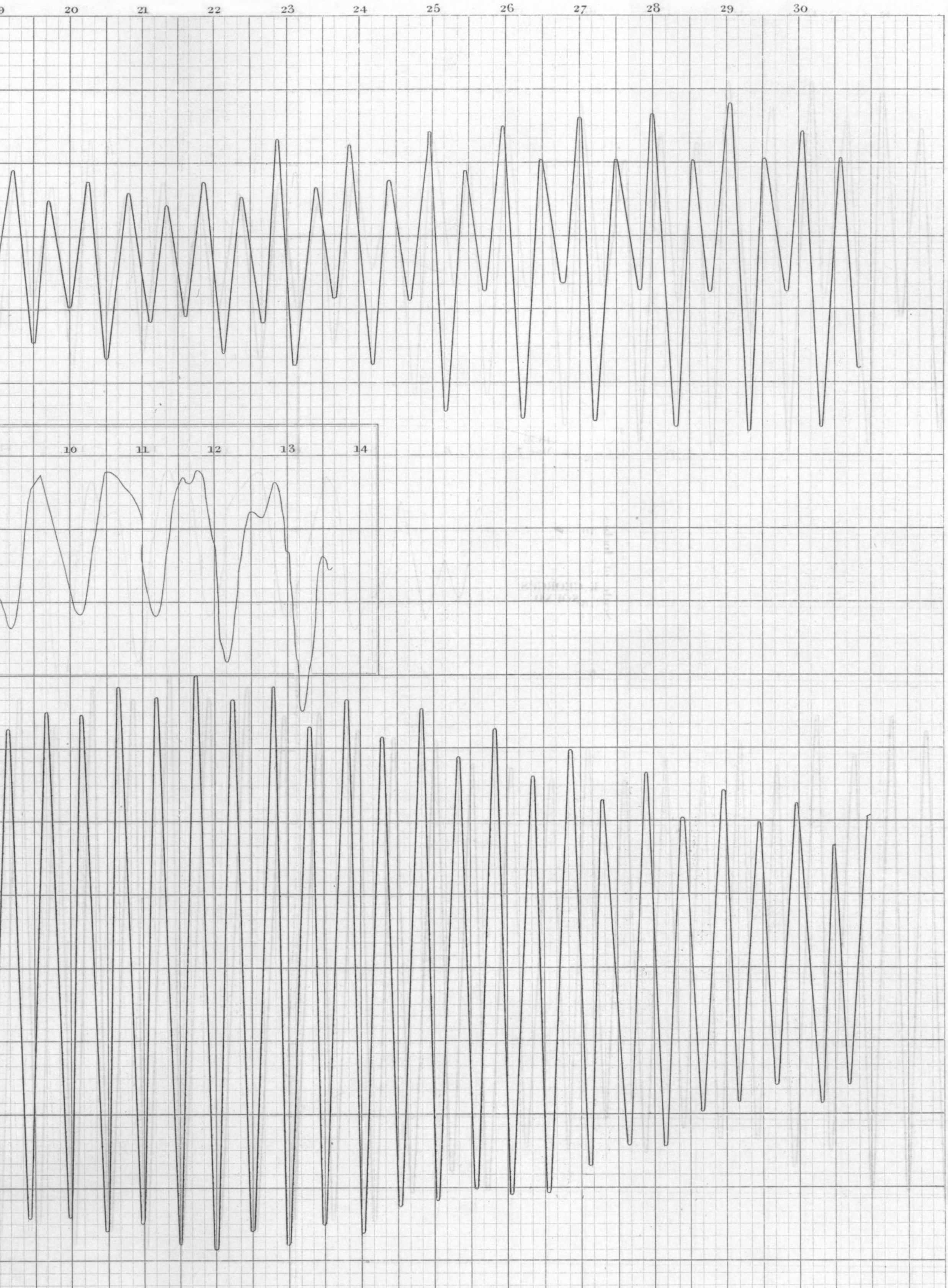
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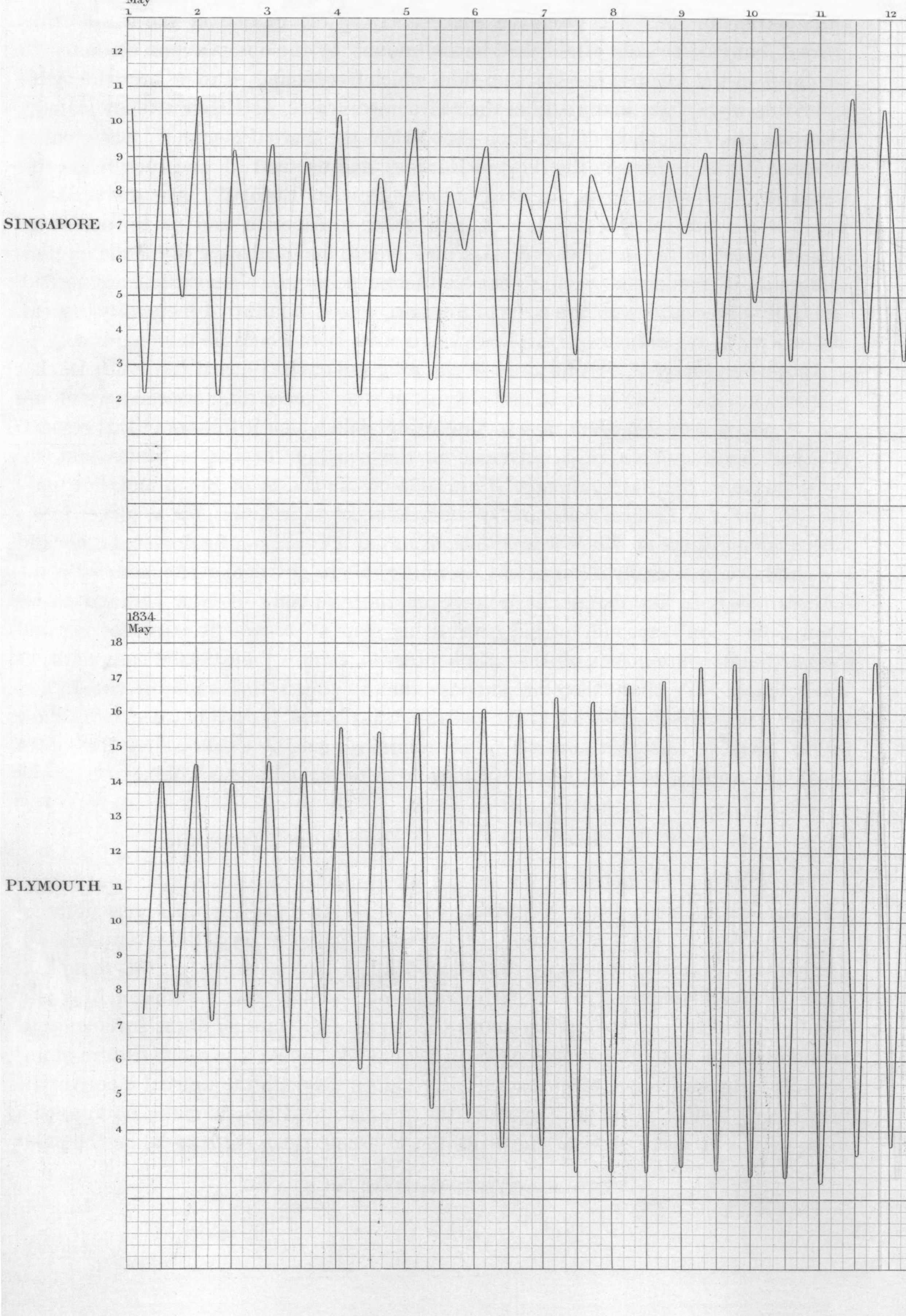
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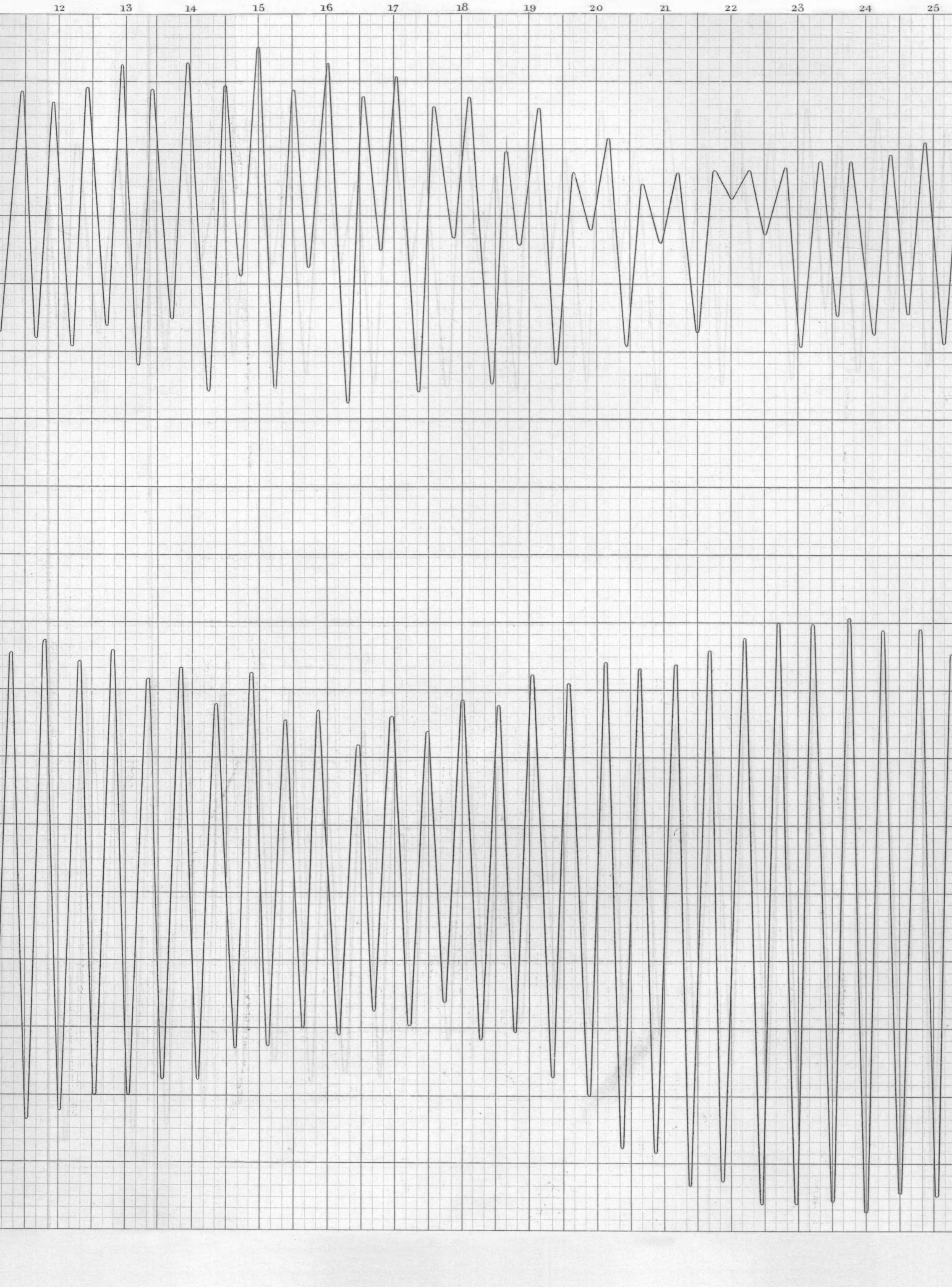
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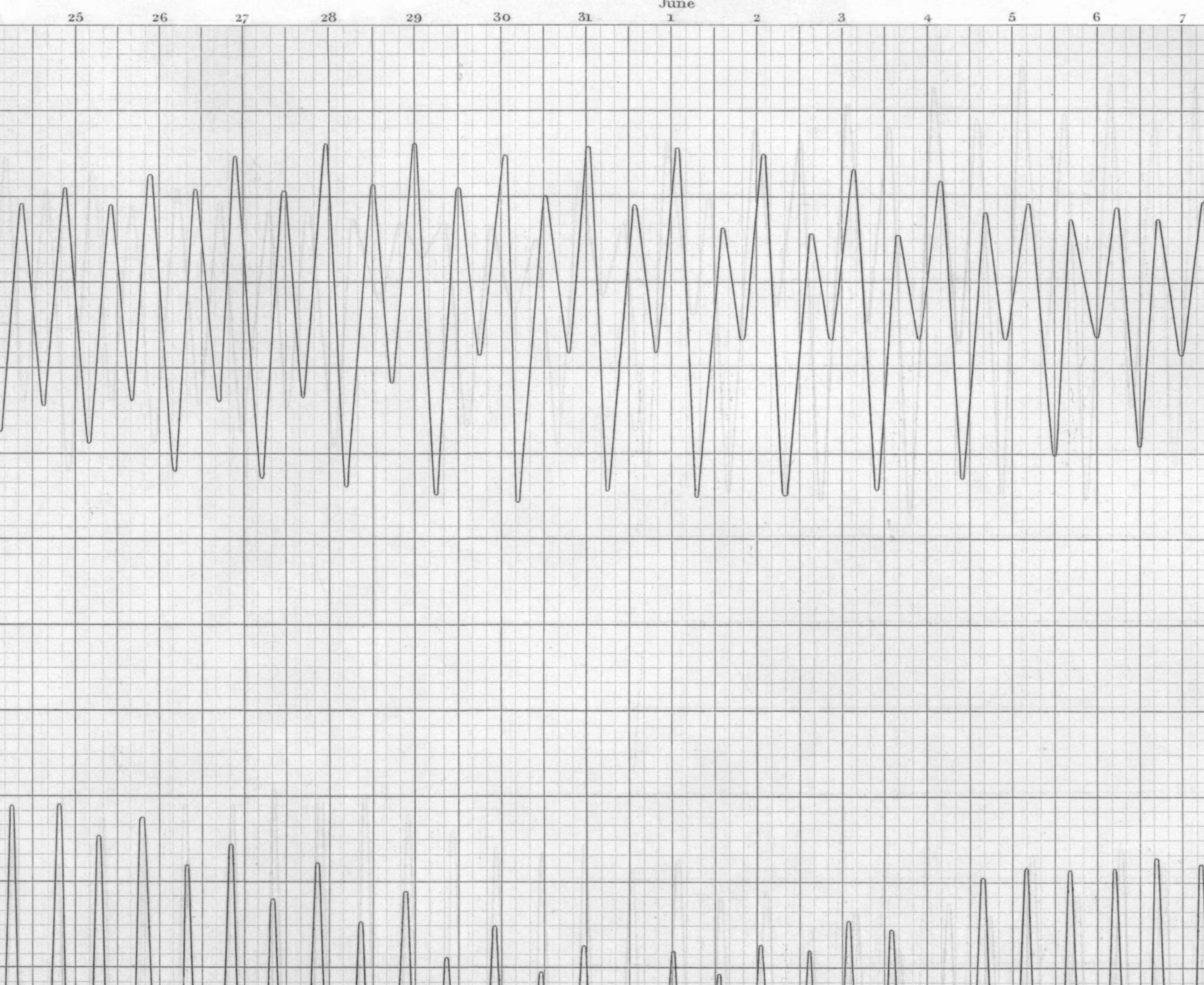
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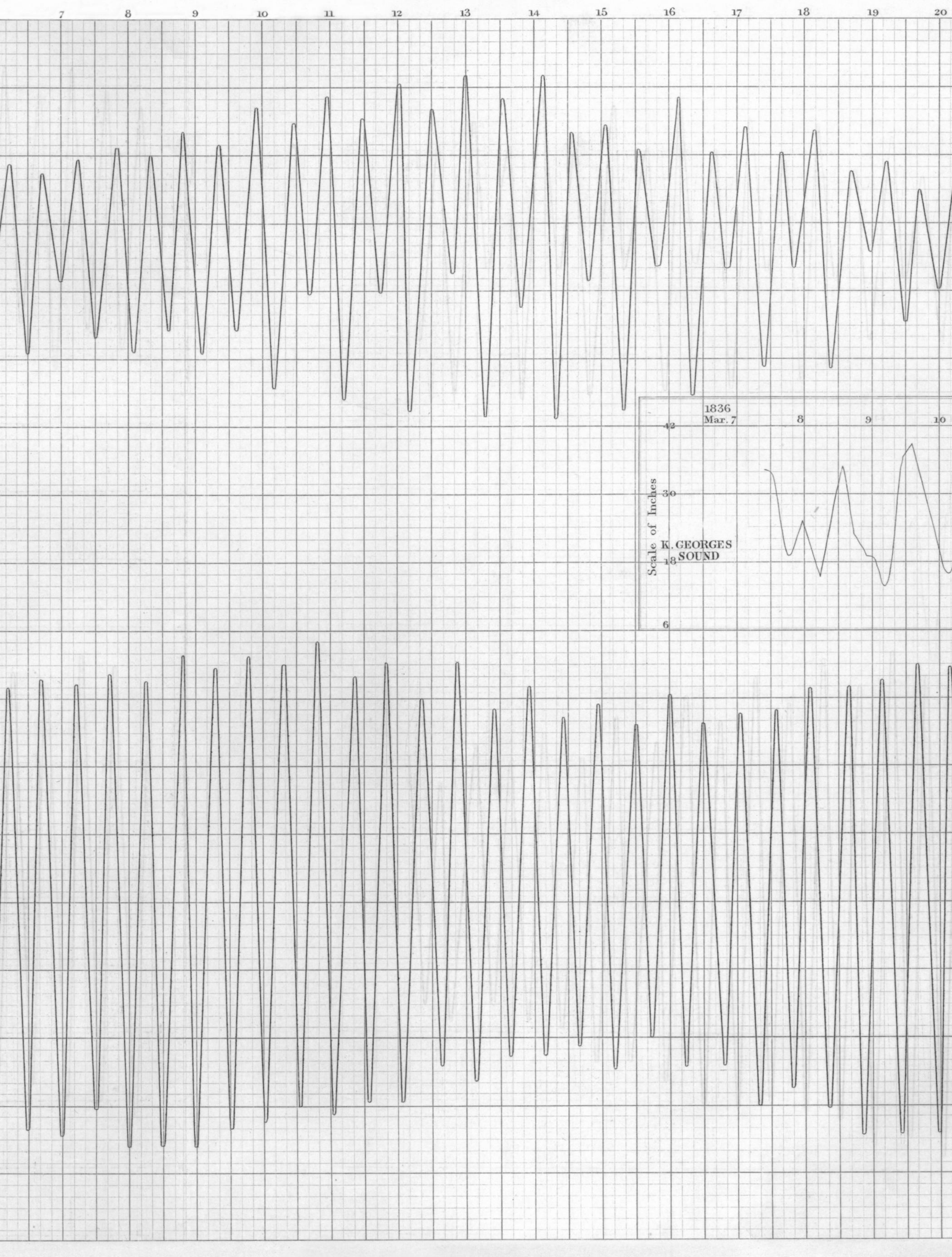

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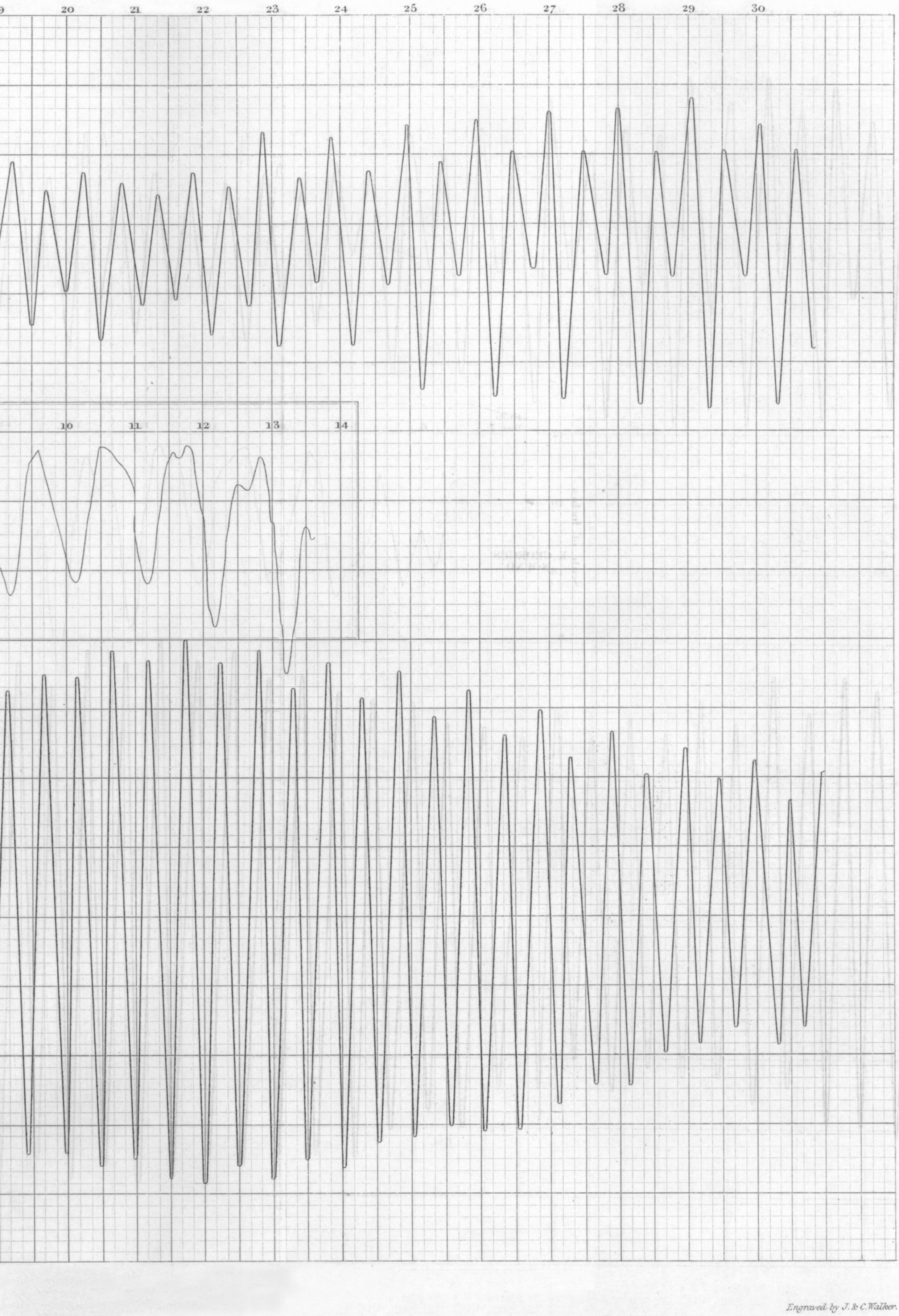
Scale of Inches
K. GEORGES SOUND



Engraved by J. & C. Walker.

of disappearing; and the progress of this alternation affects the tides as much as the independent alternation of springs and neaps.

It is easy to conceive the diurnal inequality carried a little further than it is at Singapore; so that at a certain stage of it the alternate tides would vanish. This is equivalent to supposing the highest low water and the lowest high water to have the same height.

There are statements of navigators respecting various places at which there is "only one tide in twenty-four hours." From what has been said it appears that this may happen during a part of each semilunation by the effect of the inequality now under consideration, but that it cannot in this way be constantly the case.

I am fortunately enabled to throw some light on this subject by the kindness of Captain Fitz Roy. King George's Sound on the south coast of New Holland is one of the places to which these *Single-day Tides* have been ascribed*. In March 1836 Captain Fitz Roy, aware of the interest of this position in respect to tide phenomena, caused observations to be made every half hour for some days, and for a portion of the time, every quarter of an hour. The result was that on March the 7th and 8th there were two very unequal tides, and that on the 9th and 10th there was only one tide; but a recession and return in the high water, which had been barely perceptible on the 11th, became more and more marked on the 12th, 13th, and 14th, so as again to give two tides each day. Thus at this place it appears to be only at one particular period of the semilunation that we have a single-day tide, agreeably to our general view. I insert the curve of the motion of the surface at King George's Sound in Plate IV.

The single-day tides of Tonquin† were referred by Newton to the interference of two tides, which arrive by different channels. The great diurnal inequality of Singapore, which is in the same seas, appears to be clearly due to the effect of the moon's declination; and the establishment of this point, and the circumstances ascertained to occur in the reputed single-day tide of King George's Sound, throw some doubt on the explanation just referred to, which cannot be removed till the tides of those seas have been more fully observed.

Sect. V. *On the Mean Height of the Sea.*

The question of the fluctuations of the mean height of the sea is not especially connected with the diurnal inequality. But as the curves which I had to draw in the course of this investigation give me the means of exhibiting very clearly these fluctuations, I will here say a word on the subject.

In Plate II. a line is drawn representing the *mean height*; that is, the height midway between low water and high water each day. It is obtained by taking the mean of the two curves of high and low water by which the diurnal inequality is cut off. The same is done for Singapore in Plate III.

* Flinders, vol. i. p. 71. King, vol. ii. p. 380.

† See Philosophical Transactions, vol. xiv. p. 162.

It appears that in all these cases the mean height of the sea is very nearly constant. This is most remarkable at Singapore, where, though the successive low waters often differ by six feet, the mean level only oscillates through a few inches. At Plymouth the mean level is not quite so steady. The fact is, that at that port the low water varies more by the difference of springs and neaps than the high water does; and hence the mean level slightly follows the low water, and is lowest at spring tides, and highest at neap tides, or perhaps more exactly a day or two later.

"The level of the sea at low water," a phrase sometimes used by surveyors, is altogether erroneous, and may lead to material error. From the instances just quoted (and indeed from the nature of the case) it is certain that the mean height of the sea is far more nearly constant than low or high water, under whatever assumed conditions. A *level surface* drawn from any point (that is a surface of *stagnant* water) would probably be nearly parallel to the points of mean water at different places. This becomes more manifest when we consider that at places near each other the tide often differs greatly in amount. At St. David's Head in Pembrokeshire the range of the tides is near thirty feet; on the opposite coast of Ireland it is only two or three: if the sea were level at low water the difference of the mean heights on the two sides of the Channel (which is only about fifty miles) would be fourteen feet. Such an average elevation of one side of a narrow sea above the other is quite inconsistent with the laws of fluids.

I cannot conclude this paper without again pointing out that a great number of curious facts in fluid motion are established by these Tide Researches, of which it may be hoped the theory of hydrodynamics will one day be able to render a reason. Why is it that at places near each other the range of the oscillations of the sea from low to high water is so different? Why is it that the sun affects the low water at Plymouth more than the high water, and that the moon's declination at Singapore affects the low water four times as much as the high water, while at Plymouth it affects it less? Above all, why is it that while the effect of the sun, and of the moon's declination and parallax, in the monthly course of the tides, produces the effect due to the equilibrium of the forces in one or two days, the moon's declination does not produce its effect upon the diurnal oscillation till after three, four, five, and six days; and in some cases probably not till the moon is exerting forces which tend absolutely to reverse the effect?

TABLE of the DIURNAL INEQUALITY of the Height of High Water AT PLYMOUTH.
To be used with the moon's declination *four days anterior*.

For *N.* decl., *add* to the tide following moon's S. transit, *subtract* from the tide following moon's N. transit.
For *S.* decl., *subtract* from the tide following moon's S. transit, *add* to the tide following moon's N. transit.

Moon's Declination	0° to 4°	5° to 9°	10° to 14°	15° to 18°	19° to 21°	22° to 24°	25° to 26°	27° to 28°	29°	30°
Diurnal Inequality	0in	1in	2in	3in	4in	5in	6in	7in	8in	9in

Postscript.

I will take the liberty of mentioning the only way in which it appears to me mechanically possible to conceive the slow propagation of the diurnal inequality which I have described in Sect. III.

If we suppose equal semidiurnal tides to be propagated along the length of a wide canal; and if we suppose, in addition to these, a *transverse* oscillation of the water to take place in the direction of the width of the canal, the time of this oscillation (from maximum to maximum) being a whole tide day; we shall have successive tides alternately greater and less by a diurnal inequality. And we may easily suppose this transverse oscillation to be propagated *gradually and slowly along* the canal, by the contact of the particles of the water. In this manner we may represent phenomena following laws like those above described.

But it may be further observed, that we may conceive the semidiurnal tide, as well as the diurnal inequality, to be propagated along the canal by means of transverse oscillations, the time of this oscillation being half a lunar day; and the rate of propagation of this undulation may easily be supposed to be different from that of the diurnal oscillation. In this way we may conceive the possibility of the different inequalities of the tides being propagated from place to place at different rates, and thus having different epochs, as from the recent researches on the subject contained in the Philosophical Transactions they appear to have.

Moreover, it is by no means necessary, in order to make this explanation applicable, that the transverse undulations should be perpendicular to the direction in which the tide is propagated: they may be oblique to it at any angle, and the result will still be the same.

It appears possible, also, that such a supposition may be modified, so as to explain other phenomena of the tides; for instance, the smallness of the tides in the central parts of wide seas.

But the application of such a supposition to the actual phenomena of the ocean, and the determination of those tracts of sea which must, on this view of the case, be looked upon as tide-canals, would be a matter of no small difficulty, even if our materials were sufficient for the purpose, and would probably be impossible without more knowledge of the tides on the shores of the great oceans than has yet been published.

Trinity College, Cambridge,
May 5, 1837.